NATIONAL BUREAU OF STANDARDS REPORT

9895

THE PERFORMANCE CONCEPT

Its Application to Hospital Floor Coverings

Sponsored

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Public Health Service

U.S. DEPARTMENT OF COMMERCE

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Mr. Howard W. Spence and Mr. Corwin Strong, Clinical Center, National Institutes of Health, Bethesda, Maryland

Mr. Thomas H. Boone, National Bureau of Standards

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1.0 OBJECTIVE OF THE STUDY

The objective of the study was to develop performance criteria for hospital floor coverings. Performance requirements were to be determined by a field survey of hospitals. Having determined the requirements, performance criteria were then to be developed. Where practicable, test methods were to be selected or developed to implement the performance criteria.

2.0 SCOPE

The scope of the study as stated in the Research and Technology Resume dated January 7, 1966 was quite broad. The "Technical Objectives" were "To develop performance criteria for hospital floor coverings". Specific areas which were included in the original project proposal were slip hazard, noise reduction, and serviceability and soil transport. Noise reduction is to be the subject of a separate report. Flammability, while important, was not included in the scope of the investigation. Properties included under serviceability and soil transport were soil transport; staining; replacement or patching; characteristics of floors according to intended use; and resilience and fatigue. Characteristics of floors according to intended use referred to performance characteristics of special areas in a hospital, as patients' rooms, corridors, etc.

Later the scope was limited to certain performance characteristics by agreement between the staffs of the National Bureau of Standards Building Research Division and the Public Health Service. Selection of these characteristics or factors was based on relative importance and availability of funds and manpower. The selected factors are discussed under headings 2.1 - 2.11. Factors 2.1 - 2.5 are related to health, safety, and essential hospital operations. Factors 2.6 - 2.11 are related to maintenance, cost, and convenience.

2.1 Effect on biological environment

In selecting a floor covering for a hospital it is essential to know what effect it will have on sanitation and spread of disease. Of course this is closely related to soil transport (2.5) but microbiological studies require the assistance of specialists in that field. Such studies involve air and surface sampling to determine whether various floor coverings harbor, retain, transport, and spread microorganisms.

2.2 Slip hazard and resistance to wheeled equipment

Slip hazard and resistance to wheeled equipment are related since they both involve frictional measurement. However, slip hazard is related to the safety of pedestrians, while resistance to wheeled equipment affects the energy requirements for the operation of essential equipment.

2.2.1 Slip hazard

A floor covering should be designed to minimize accidents due to slipping or tripping. A slip may be defined as a pedestrian's sudden loss of traction in a forward or backward direction. A trip is a sudden halt in a pedestrian's progress. The person may stumble over an unexpected interposed object or may balk because of a sudden increase of friction in the walkway. Having slipped or tripped, the resilience (2.4) of the floor covering may be a factor in the degree of injury suffered. Slip hazard is related to the coefficient of friction of the floor covering.

2.2.2 Resistance to wheeled equipment

Moving wheeled equipment on the floors is an important part of hospital operations. Patients' beds are moved occasionally and patients are brought in or taken to the operating suite etc. on wheeled stretchers. Food and linens are brought in on heavy wheeled carts. Sometimes it is necessary to bring a mobile X-ray unit into a patient's room. Obviously the floor covering must not impede the movement of wheeled vehicles.

2.3 Static electricity generation and dissipation

The friction of rubbing dissimilar materials is likely to develop a static charge. A charge may be produced by a person walking across a floor, especially if the floor is covered with carpet. Carpets, especially those made of synthetic fibers, are more likely to develop static charge between the floor and persons walking on them than are smooth surface floors. Static is more of a problem under low humidity conditions and is never a problem when the relative humidity is over 50 percent. Static charge is a serious hazard in hospital operating rooms and elaborate precautions are taken during operations. Floors are made of electrically conductive materials in a modern hospital operating room. Static charge is an annoyance and possibly a hazard in patients' rooms, especially if oxygen is to be administered. It the floor is electrically conductive and properly grounded, any static charge which is developed is rapidly dissipated. Hence electrical conductivity is the physical property related to this performance characteristic.

Conductive materials, as carbon black, are incorporated into smooth surface floor coverings and conductive floor finishes are also used to solve this problem. Carpets are often treated with anti-static materials or are constructed with chemically modified fibers or with metal fibers woven into the pile.

2.4 Resilience as related to fatigue and bodily protection

To most people, soft floor coverings feel more comfortable and luxurious. The subjective impression, at least initially, is that walking on soft floor coverings should be less tiring and that there is less danger of bodily injury from falling. However, this property may be pyschological rather than physiological. If there is any physiological advantage in using certain floor coverings, this must be related to a measurable physical property. Resilience then becomes an important performance characteristic.

2.5 Soil transport

Floor coverings pick up dirt mainly from shoes of persons walking in from the outside. A large part of this dirt is deposited near the entrance. For this reason, walk-off mats have become popular. Of course, walk-off mats will not remove all of the dirt, especially when the mats become soiled and approach a kind of dirt saturation. In fact, dirt may be picked up from dirty mats and deposited on other floor areas or dispersed into the atmosphere of the building. Likewise, other floor coverings may transfer dirt to other floor areas or into the air. This is what is called soil transport. Surface borne soil transport is transfer of dirt from one floor area to another and air borne soil transport is the transfer of dirt from the floor to the air.

If a floor covering is to retain the soil deposited on it instead of spreading it to other areas or dispersing it into the air, it must have some attraction for dirt. At the same time, it must not have too strong an affinity for dirt or it will become easily soiled and hard to clean. Some balance of properties is needed and some areas will need a floor covering which attracts and retains dirt to a greater degree than would be desirable in other areas.

2.6 Floor covering economics

The economics of floor coverings, while not a functional attribute, is an important factor in selection. Floor covering economics can be expressed in annual terms. The total annual cost of floor covering is the sum of annual depreciation, repair and replacement (2.8) and maintenance. Depreciation is a function of initial cost and the life of the floor covering. The life of the covering is related to durability (2.7). Maintenance cost is affected by soilability and cleanability (2.9) and staining and removal of stains (2.10). Maintenance cost cannot be measured by laboratory tests but only by studies in actual installation. A number of studies have been made but for various reasons are subject to criticism. The most detailed studies have been sponsored by commercial interests. All parameters have not been adequately defined, especially detailed specifications on the floor coverings used in the studies.

2.7 Durability

It is important for a floor covering to be durable or to retain its properties for as long a time as possible. All floors are subject to wear, which changes the appearance, thickness, and integrity. In time a floor covering will actually wear through its thickness, as by abrasion from shoe soles etc. Before the material is actually worn through, the texture and pattern will be destroyed. Smooth floor coverings will scratch and mar and become hard to clean. Carpets or pile floor coverings will become matted, torn, and spotted.

2.8 Repair and replacement

There is no way in which repair and replacement of floor coverings can be measured in the laboratory. This is an art known to skilled workmen. Dealers, installers, manufacturers of floor coverings, and trade associations are knowledgeable in the repair and replacement of their products. Repair and replacement is a part of the economics of floor coverings (2.6) and can be evaluated only by field studies and surveys, combined with a thorough knowledge of various types of floor coverings.

2.9 Soilability and cleanability

Soilability refers to appearance as much as to the actual quantity of dirt retained. Aside from appearance, the user's concern is with sanitation, which is related to soil transport (2.5). The criteria for cleanability are the same as for soilability; that is, appearance, dirt retention, and soil transport; but after cleaning. In order to develop a performance standard for cleanability, it is necessary to devise a standard cleaning method. This must be related to methods actually used in maintenance.

2.10 Staining and removal of stains

This factor is a special case of soilability and cleanability (2.9), is a part of maintenance, and hence related to floor covering economics (2.6). Stains are local changes in appearance of a floor covering due to spillage, which require special treatment. As a rule, prompt spotting treatment is necessary, as many stains are more difficult to remove after standing for several hours. Staining is treated as a separate factor because removal or spotting is an item separate from routine maintenance. Appearance is the criterion for staining and stain removal. There are many common materials which stain floor coverings, especially carpets, and removal or spotting is a complex art. For this reason, it is difficult to devise a test method to implement a performance standard.

2.11 Moisture permeability and retention

It is important from the standpoint of maintenance and sanitation that floor coverings should not soak up water or allow water to penetrate through to the subfloor and become trapped. This situation might provide a breeding ground for microorganisms. A spongy type of material might remain wet after spillage or wet cleaning. This might result in wet feet, fermentation, mildew, fungus, and growth of pathogenic organisms.

3.0 BACKGROUND

3.1 Public Health Service Needs

The Public Health Service has requested a study of performance tests to evaluate the behavior of floor coverings in hospitals. Special purpose buildings, such as hospitals, require more intensive analysis in the selection of floor coverings than do general purpose buildings.

A number of performance requirements were suggested in April, 1966 by the Public Health Service Division of Hospital and Medical Facilities. In addition to factors already mentioned, these included moisture retention; soil accumulation, retention, and removability; ventilation rates and patterns; wear characteristics; resiliency; effect on biological environment; aesthetic factors; and cost of maintenance.

The following is a list of performance characteristics included in the scope of this investigation as discussed in section 2.0:

Factors related to health, safety, and essential hospital operations:

2.1 Effect on biological environment

2.2 Slip hazard and resistance to wheeled equipment

2.3 Static electricity generation and disipation

2.4 Resilience as related to fatigue and bodily protection

2.5 Soil transport

Factors related to maintenance, cost, and convenience

2.6 Floor covering economics

2.7 Durability

2.8 Repair and replacement

2.9 Soilability and cleanability

2.10 Staining and removal of stains

2.11 Moisture permeability and retention

3.2 Field studies

In order to evaluate floor coverings, both field and laboratory studies are essential and should be correlated. Field studies may be reports of actual installations or experiments under use conditions.

3.2.1 Reports of installations of carpets in hospitals by others

Lutheran General Hospital, 1775 Dempster St., Park Ridge, Illinois 60068

Dr. James G. Shaffer, Director of Microbiology and Hospital Epidemiology

Report presented by Dr. Shaffer at American Public Health Association meeting, October 21, 1965

James G. Shaffer, "Microbiology of Hospital Carpeting", Health Laboratory Science vol. 3, No. 2, 73 (April, 1966)

James G. Shaffer, Iris Key, and Beatrice Thomas, "High-Power Vacuum Keeps Bacteria Low in Care of Carpeting", The Modern Hospital, October, 1966

Study covered period 1960-1965 and included microbiological properties

Total area carpeted approximately 24,000 sq. ft., two floors carpeted with acrylic and two with wool.

Carpet furnished and installed by American Carpet Institute

Carpet was vacuumed daily with shampooing in medical and surgical floors at 6-month intervals. It was concluded that carpet has no adverse effect on the environment as measured by microbiological means.

Whittier Hospital, 15151 Janine Drive, Whittier, California 90605

Reports to California Dept. of Public Health, Bureau of Hospitals, 2151 Berkeley Way, Berkeley, Calif. 94704 by the following members of the staff of Whittier Hospital:

Mrs. Betty J. Cain, Executive Housekeeper, June 15, 1964
Dr. Stanley K. Wong, Pathologist, June 12, 1964
Mr. Doyle R. Taylor, Administratior, August 10, 1964
Mrs. Betty J. Cain and Mr. Doyle R. Taylor, Sept. 15, 1964.

Study covered period 1964

Sponge bonded nylon carpet was installed by the California Dept. of Public Health in the following areas:

Administrative offices and corridor
Main Lobby and visitor waiting areas
Public, Patient, and Personnel dining areas
Corridor of a work area surrounding a nursing unit
Personnel lounge
Doctor's lounge
Nursing lounge
Patient rooms
Secondary corridor to Delivery Room
Secondary corridor to Kitchen

Study included lint reduction, maintenance cost, microbiological effects on environment, noise reduction, psychology of patients, safety, and spots and stains.

It was concluded that maintenance cost was less; carpet reduced bacterial count; the hospital had a less "institutional" look; there were fewer slipping and falling accidents; and there was less noise.

Barnes Hospital, 600 South Kingshighway Blvd., St. Louis, Mo. 63110

Joseph T. Greco (Associate Director), Hospitals vol. 39, June 16, 1965

Report submitted to the American Carpet Institute by Industrial Sanitation Counselors, 2934 Cleveland Blvd., Louisville, Ky. 40206

Study covered period 1962-1965

Total area carpeted 7,214 sq. ft. - acrylic carpet in the corridor of the main lobby and three floors in the new addition to the surgical wing. The fourth floor was covered with vinyl floor tile.

The study included maintenance of carpet vs. tile, microbiological effects, noise reduction, flammability, reactions from patients and personnel, rolling friction, safety, static buildup.

There was little difference in maintenance cost between carpet and vinyl tile. Bacterial counts on the surface and airborne bacterial counts were about the same in carpeted and uncarpeted areas. It was found that carpet eliminated most impact noises and reduced airborne noises. Sound levels were less in carpeted areas than in noncarpeted areas. There were no complaints from patients about carpet and some favorable comments. Some nurses complained about pains in their legs from walking on carpet,

especially with rubber cushioned shoes. Some difficulty was experienced with rolling heavy wheeled equipment. For this reason, some casters were changed and a 1/4-inch thick rubber pad used instead of a 3/8-inch thick fiber-impregnated pad. Carpet reduced injuries due to falls; during the study there were no reported sustained injuries from falls in carpeted areas and 19 reported injuries from falls in noncarpeted areas.

Genesee Hospital, 224 Alexander, Rochester, New York 14607

Jane Bedford and Edward Sardisco, "Carpet Stands Test of Time and Traffic", The Modern Hospital, vol. 102, No. 2, 108 (Feb., 1964).

Edward Sardisco, "Bacterial Growth - Carpet vs. Resilient Floors", Eastern Regional Conference, Institute of Sanitation Management, March 14, 1966

Study covered period 1958-1963.

Area carpeted: Sixth floor (patients), including 8- by 250-ft. corridor, 32 private patients' rooms and alcoves connecting each pair of rooms.

Carpet used: 100% wool from Seamloc Carpet Co., Sanford, Maine, with ethyl cellulose backing and 32 or 48 oz. castle hair on jute padding. Purchased and installed by hospital.

Study included maintenance cost of carpet vs. vinyl asbestos tile, microbiological effects, noise reduction, reactions from patients and staff spillage and stains.

There was less noise from footsteps and wheeled vehicles in the carpeted areas and no slipping or sliding.

Less time was spent on maintenance of carpet than of tile. When the carpet was first installed, it was shampooed every six months; then it was shampooed every three months with a rug scrubbing machine. In addition, the carpet was vacuumed daily.

Blood, urine, oil, grease, medicine, beverages, and food have been spilled but were removed with lukewarm water and a synthetic detergent. Red ink stains could not be removed and the stained portion had to be cut out and replaced.

Studies of airborne organisms, floor cultures, and cultures of vacuumings indicated that carpet is not a bacteriological hazard. Owing to the lack of previous investigations and standard methods, the studies were not very comprehensive and a simple test method was used.

Kettering Memorial Hospital, Kettering, Ohio 45429

(Mrs.) Mildred Chase (Assistant Administrator), Hospital Management, August, 1965

A carpeted area of 30,750 sq. ft. was compared to an area of 10,050 sq. ft. covered with vinyl asbestos tile. Maintenance cost of the carpet was considerably less. The carpet was vacuumed and spot cleaned daily; shampooed at least twice a year; and fogged monthly with a germicide. The initial cost of the carpet was greater and the expected life about 10 years; whereas vinyl asbestos tile was expected to last about 15 years. However, lower maintenance costs more than offset the higher capital outlay of carpet.

Carpet reduces noise by at least 50% and in corridors it can eliminate clatter from utensils and dishes on carts, noise from wheeled vehicles, and click-clack from visitors' heels.

Some employees who are not used to carpet complain of legs aching for a few days but later find it more comfortable.

There are less slips and falls on carpeted floors and if there is a fall it is less likely to cause injury.

The author reported research on testing procedures for bacterial contamination and fogging with germicidal solution. There was evidence of a residue of germicide being built up on carpeting.

Procedures were worked out for removing stains and a study was made of the proper vacuum cleaning equipment.

Royal Victoria Hospital, Montreal 2, Canada

Madeleine Levason, Canadian Fabric News, Canadian Textile Journal, Sept. 25, 1964

Study covered period 1962-1964.

Installation was in the renovated Ross Memorial Pavilion. This included the corridors, 13,000 sq. ft., covered with wool carpet, 5/16 in. pile height, density 76 tufts per sq. in., laid over underpadding on top of the old cork tile floor. Carpeting in the rooms was wool with latex backing and in the solariums a wool-nylon weave carpet was used.

The carpet was vacuumed daily; dry shampooed every 2-3 months, and wet shampooed once. Spots were cleaned immediately.

The carpeted floors were much quieter and the maintenance cost was 40-45% less. Heavy food carts, beds, and other vehicles presented no problems of stretching or wrinkling the carpet.

The American Carpet Institute reported studies in the following hospitals which showed maintenance costs to be less with carpet than with non-textile resilient floor coverings:

Grace - New Haven Community Hospital, 789 Howard Ave., New Haven, Conn.

Glendale Sanitarium and Hospital, 1509 East Wilson Ave. (P.O. Box 871), Glendale, Calif.

Jackson Hospital and Clinic, Inc., 1235 Forest Ave., Montgomery, Ala.

Fresno Community Hospital, Fresno St. (P.O. Box 1232), Fresno, Calif.

Magee - Women's Hospital, Forbes Ave. and Halket St., Pittsburgh, Pa.

At Grace - New Haven, Jackson and Fresno Hospitals, studies showed that carpet was not a bacteriological hazard.

Fresno Community Hospital Acoustics Study

Daniel Fitzroy, West Coast acoustical engineer and consultant to the Fresno Community Hospital reported on a Public Health Service investigation the most annoying sources of noise in a hospital. The noise sources were found to be in the following order with the beginning of the list the most annoying:

1. Radio and television
2. Staff talk
3. Crying babies
4. Outside traffic
5. Employee-created noises
6. Service equipment noise
7. Mechanical equipment
8. Patient service facilities
9. Patients and visitors
10. Slamming doors and windows

Of the 10 top annoying noise sources, roughly half fall into the airborne category and half into the impact noise category. The American Carpet Institute, who reported this study, claims that impact noises are almost completely eliminated through carpet use.

3.2.2 Observations of carpet installations by NBS staff

Two installations were observed, one in a hospital and one in a food store. Both of these installations were carpeted with a low pile, closely woven nylon material with attached sponge rubber cushion.

Coronary Care Unit, Holy Cross Hospital, Silver Spring, Maryland

This unit was carpeted in the fall of 1966 and was observed in March, 1967 and April, 1968. Nurses and maintenance men expressed satisfaction with the installation, which required only vacuuming. The carpet was said to be more comfortable and less noisy than smooth surface flooring. No difficulty was reported in moving beds and other wheeled equipment. The carpet was clean and in good condition at both inspections.

GIANT Food Store, Van Ness Center, Connecticut Ave. and Van Ness St., N.W., Washington, D. C.

The store opened March 22, 1967 and was then covered with red and blue carpet. On March 23, the carpet was observed to be rather firm to walk on but somewhat difficult to push grocery carts over. Red carpet was at the Connecticut Ave. entrance and over most of the store except for blue carpet at the exit to Connecticut Ave. and around the check-out area. The red carpet had violet tufts and the blue carpet had black and violet tufts. There was a walk-off mat at the Connecticut Ave. entrance and one at the rear at the entrance to the storeroom. On April 10, there were black spots around the vegetable and meat counters; black streaks around the dairy counter; white dust where supply carts or trucks are pushed. The carpet is vacuumed frequently during the day and spotted with a commercial all-purpose cleaner.

On July 1, 1968 the installation was inspected again. The manager said that the carpet was all original; none had been replaced. There was some fuzzing at the checkers' exits but otherwise no appreciable wear. There were walk-off mats at the entrance and near the seafood case and transparent plastic mats near the vegetable bins. In spite of this, the carpet showed numerous stains all over and there were a number of places with chewing gum deposits ground into the pile. The manager said that the cost of adequate spotting to remove these stains was prohibitive. It is somewhat harder to push carts over the carpet than over smooth surface tile but one of the checkers said that the customers were used to this and that it was not a problem.

Conclusions

From these observations, it would seem that the success of the carpet installation depends partly on the conditions of use. Carpet should be satisfactory in a well run hospital unit where skilled personnel are working and spillages are infrequent. Carpet does not seem to be vary satisfactory in a "dirty" area where a lot of food is apt to be spilled, the floor is treated carelessly, and there is heavy traffic.

4.0 LABORATORY INVESTIGATIONS

A laboratory program was conducted to develop procedures for measuring properties of floor coverings as related to performance in service. Amont the areas investigated were resistance of floor coverings to wheeled vehicles and the resilience of floor coverings as related to comfort. Information and data on these important characteristics is lacking in the open literature.

4.1 Resistance to wheeled equipment

In order to define the problem of pushing wheeled equipment on the floors of a hospital nursing unit which might be carpeted, a survey was made of this type of equipment used in the nursing units at the Clinical Center, National Institutes of Health, Bethesda, Maryland. Estimates of weight were given by the staff of the Clinical Center with the exception of the bed, loaned to NBS for the test program, which was weighed. The bed is a manual type and is about 290 pounds lighter than the more modern electrical type.

Because of its availability it was decided to use a manual type bed for laboratory studies of rolling friction. Measurements were made with the empty bed and with 300 pounds weight. Casters used in the study were new, 5 inches in diameter, 1-inch tread. Two sets of casters (four in each set) were used, one being made of hard rubber (recommended for carpet) and the other set made of soft rubber (recommended for smooth floor coverings). Tests were performed using a load-strain testing machine. A load cell was connected to the foot of the bed and attached to the crosshead by means of a pulley and cable arrangement. Tests were performed at a crosshead speed of 50 cm. per minute, with the casters or wheels aligned in the direction of pull. Floor coverings were cemented on plywood, with the exception of stretched carpet, and the plywood leveled by means of wooden shims. The equipment and alignment of the casters are illustrated in Figures 1-4.

Figure 1. Equipment for testing resistance to wheeled equipment. Platform with carpet; hospital bed and connections to load cell, pulley, crosshead of load-strain testing machine.

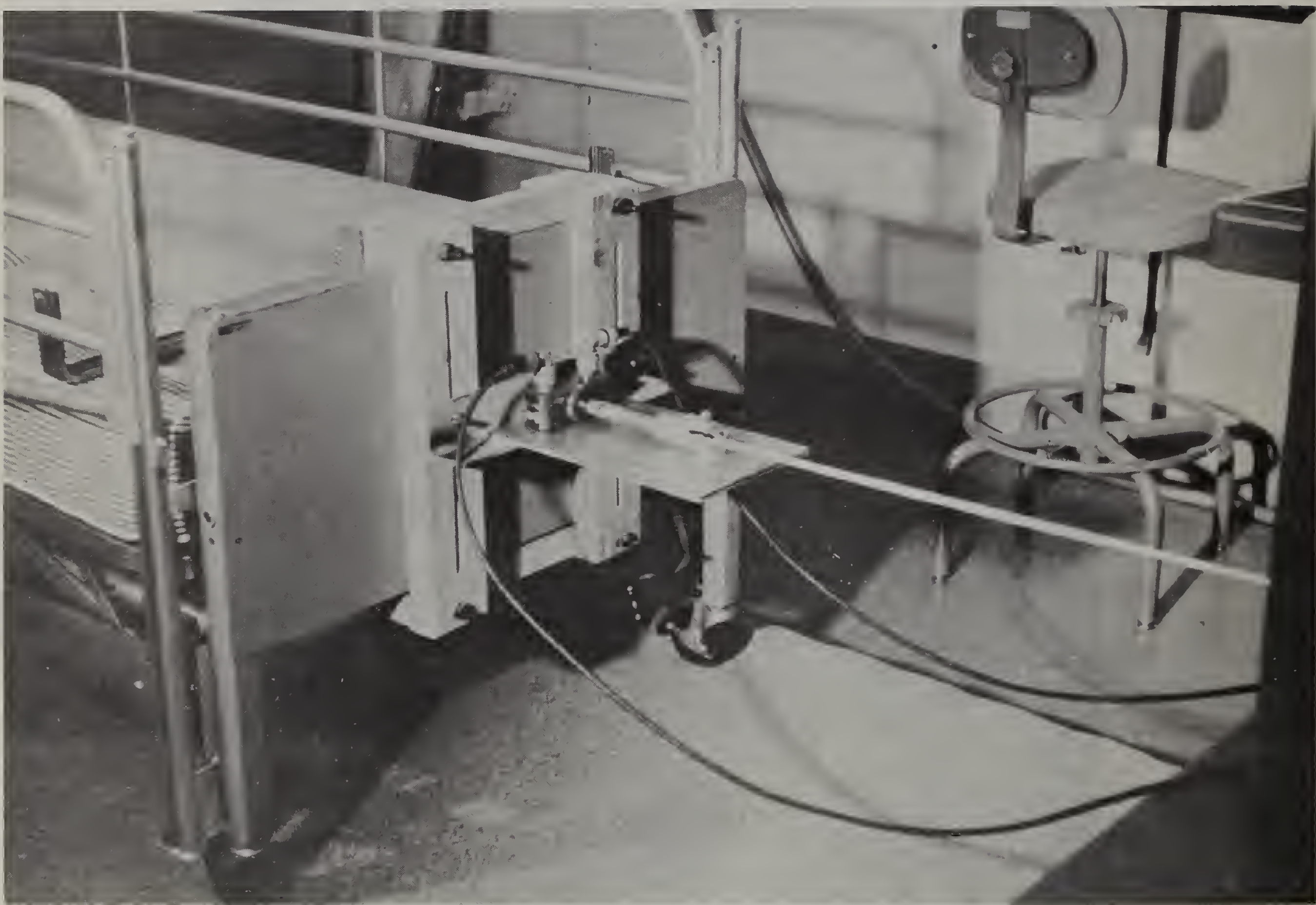

Figure 2. Detail of bed, load cell, and connections

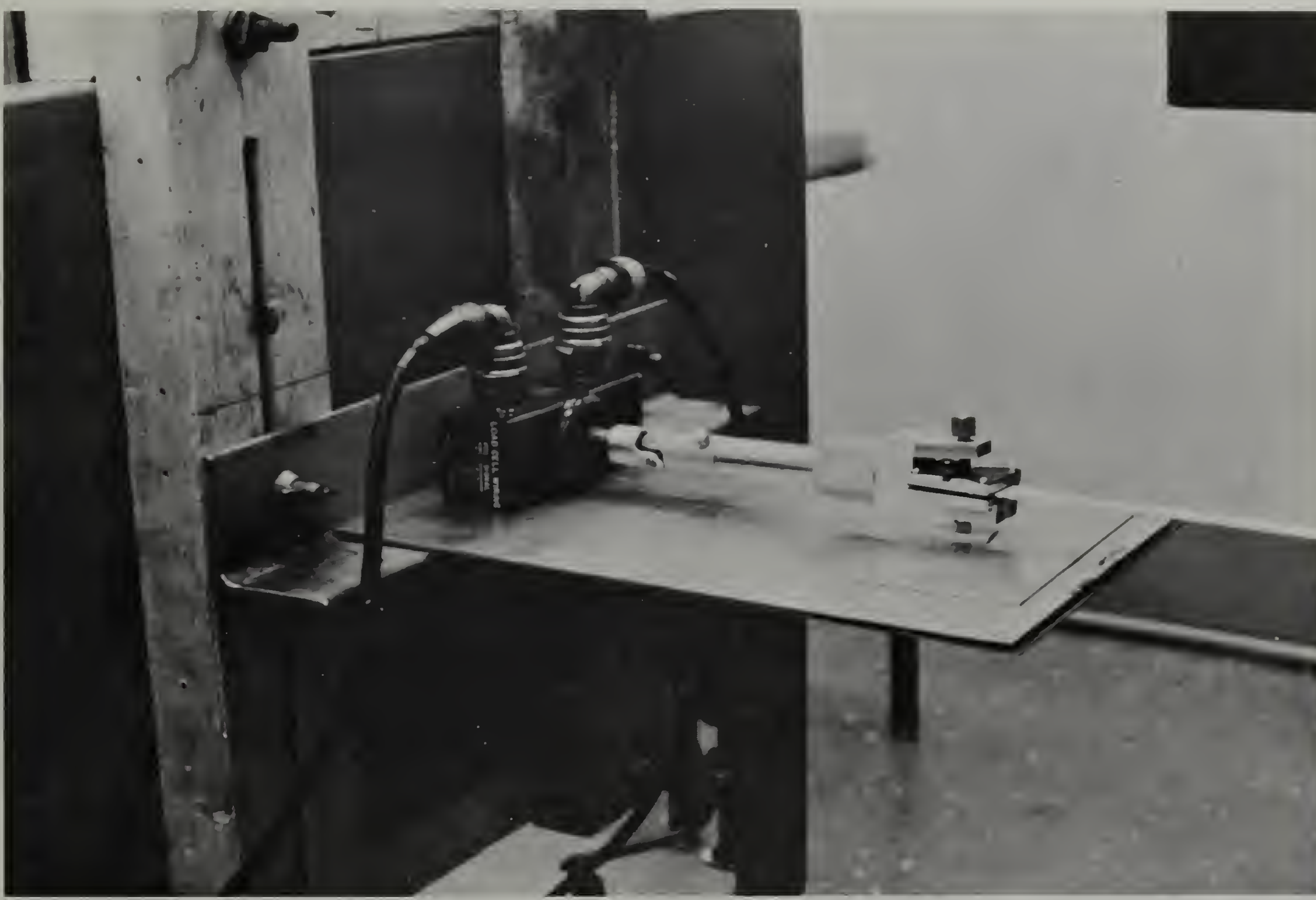

Figure 3. Detail of load cell and connections

Figure 4. Alignment of casters

Table 1. WEIGHT AND DIMENSIONS OF WHEELED EQUIPMENT IN A HOSPITAL

Equipment	Weight lb.[a]	Wheelbase inches[b]	Track inches[c]	Casters or Wheels Diameter inches	Casters or Wheels Tread width inches
Bed, manual, empty[a]	290	85	34	4	1
Stretcher, empty[a]	100	42	22	10	1
Food Cart	400	26	16	8	1-1/4
Linen cart	300-500	47	17	8	1-1/4
Mobile X-ray unit	850-1,000	21			
Front wheels			14	4	1-1/8
Rear wheels			22	10	2-1/8
Fire Department Emergency equipment	300	39	19	8	1-1/8

[a] Obviously a patient would add 100-250 lbs. to the weight of a bed or stretcher.

[b] Distance, hub to hub, between front and back wheels

[c] Distance between centers of front or rear wheels

Table 2. LABORATORY MEASUREMENTS OF STATIC AND ROLLING FRICTION

Floor Covering	Frictional Force or Load in Pounds with hard rubber casters[a] [c]				with soft rubber casters[b] [c]			
	Unloaded		300 lbs. load[d]		Unloaded		300 lbs. load[d]	
	P_S[e]	P_R[f]	P_S[e]	P_R[f]	P_S[e]	P_R[f]	P_S[e]	P_R[f]
A - Vinyl asbestos tile	11.1	5.3	24.6	13.1	12.0	8.8	28.1	21.2
B - Sheet vinyl	25.9	14.8	34.9	26.5	26.2	15.0	40.4	29.7
C - Nylon carpet	20.1	15.1	41.3	31.3	18.0	13.4	36.4	28.0
D - Nylon carpet	17.2	13.3	36.9	27.1	19.6	15.1	38.2	30.9
E - Nylon carpet	23.8	17.8	47.7	35.8	26.0	20.0	47.4	36.1
F - Nylon carpet	23.7	17.1	46.4	34.5	19.9	15.1	39.5	31.9
G - Nylon carpet	33.3	24.9	60.8	46.4	30.4	22.1	52.7	41.0
H - Olefin carpet	31.6	23.9	57.0	48.5	28.5	21.2	53.5	42.5
I - Indoor-outdoor carpet	24.1	18.2	46.8	36.2	25.5	19.2	46.5	38.0

[a] Bassick No. 15698X5RP

[b] Bassick No. 15696X5RP

[c] Hospital bed, manually operated, with spring and mattress. Total weight 290 pounds

[d] Hospital bed, weight 290 pounds, with additional 300 pounds weight

[e] P_S = Static Friction = Load in pounds required to produce motion. Maximum force recorded.

[f] P_R = Rolling Friction = Load in pounds required to sustain motion. Average steady state force recorded.

Floor coverings measured as in Table 2

A - Vinyl asbestos tile

B - Vinyl sheet floor covering with attached sponge vinyl cushion

C - Nylon looped pile tufted carpet without backing or pad

D - Nylon modified upholstery weave carpet with attached sponge rubber cushion

E - Nylon looped pile tufted carpet with attached foam rubber cushion

F - Nylon looped pile tufted carpet with solid vinyl backing

G - Nylon looped pile tufted carpet with attached sponge vinyl cushion

H - Polypropylene tufted carpet stretched over hair felt pad

I - Polypropylene needlepunched non-woven felt carpet

In general, floor coverings which appear to be soft and cushiony to walk on show more resistance to wheeled equipment. This is true of H, a carpet stretched over a hair felt pad. Carpet without pad, C, showed much less resistance and vinyl asbestos tile, A, the least resistance. Sponge vinyl cushion appears to impede the motion of wheeled equipment, as in B and G. Part of the effect in B was probably due to the embossing on the sheet vinyl surface. The test provides an objective measure of resistance to wheeled equipment and is valuable for the evaluation of floor coverings proposed for use in hospitals.

4.2 Resilience as related to fatigue and bodily protection

4.2.1 Preparation of specimens

Cement mortar panels, 10- by 10- by 1-inch thick, were used as substrates for floor coverings tested. Asphalt, vinyl asbestos, and vinyl tiles were cemented to the panels with asphalt cutback adhesive. Linoleum was cemented with linoleum paste. Backed and cushioned vinyl sheet goods were cemented to panels with special latex adhesive designed for the purpose. Nylon carpet with various cushion materials attached and without cushion was cemented to the panels with latex adhesives recommended by manufacturers of the various products.

The following procedure was used for carpet with separate pad:

> Plywood strips, 1-inch wide and 1/4-inch thick, were cemented to the edges of each panel using epoxy cement. The pad was cut to fit inside the strips and carpet was tacked to the plywood strips, stretching the carpet by means of an artist's canvas stretcher.

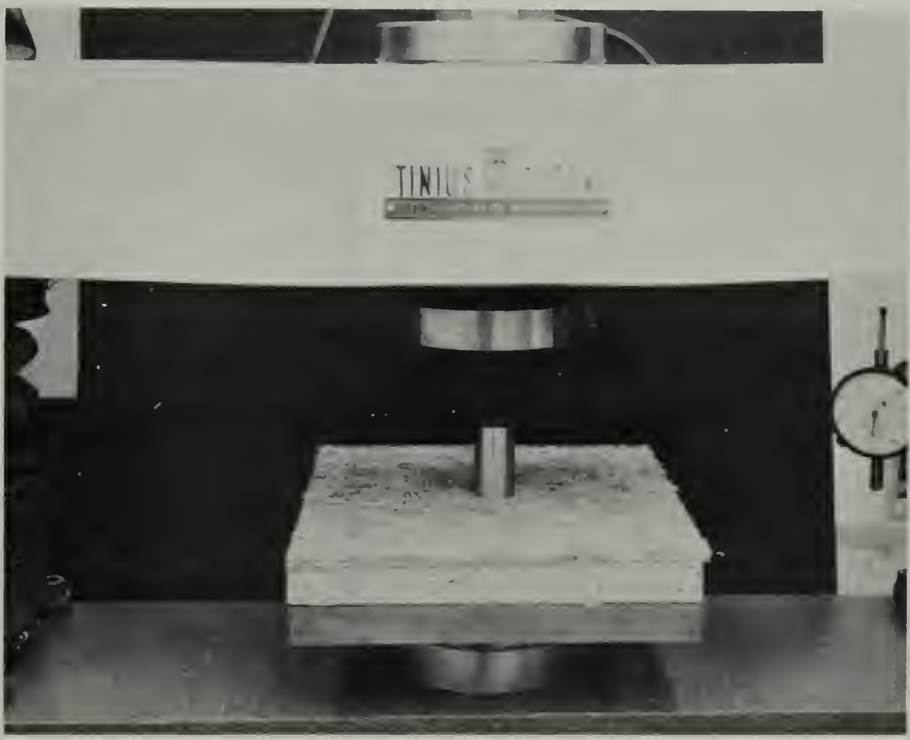

Figure 5. Apparatus and specimen for compression-recovery test. Shown from top to bottom: crosshead and load cell; cylindrical plate; cylindrical indentor; carpet sample; cement mortar panel; square steel plate; cylindrical plate.

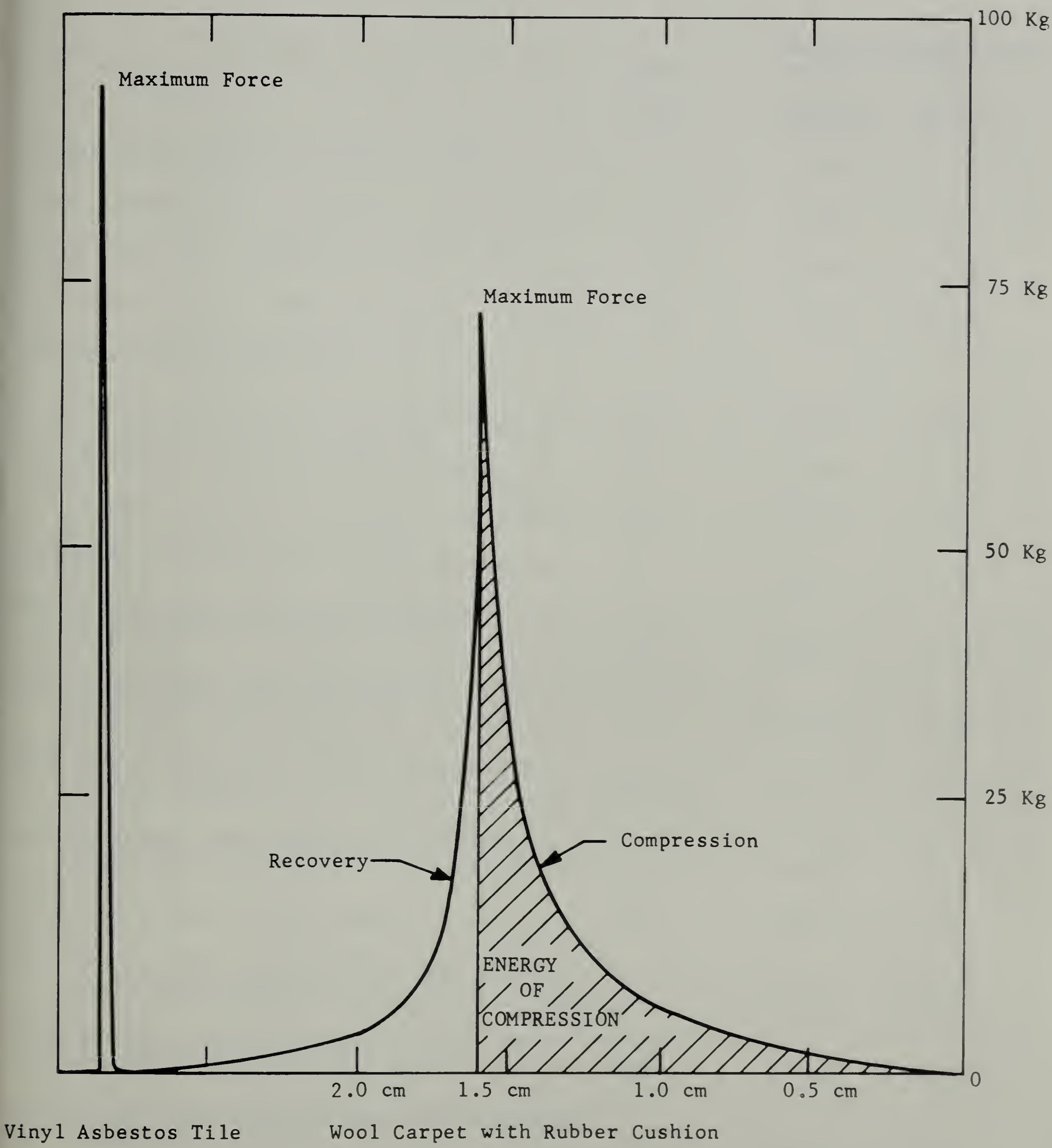

Figure 6. Typical Compression - Recovery Curves

Table 3. RESILIENCE OF FLOOR COVERINGS

	Maximum Force lbs.	Energy of Compression	
		gm.-cm. per 100 lbs.	ft.-lbs. per 100 lbs.
Asphalt tile (average of three tests).........	203	283	0.02
Vinyl asbestos tile (average of three tests)..	195	241	0.02
Solid vinyl tile (average of three tests).....	182	344	0.02
Backed vinyl sheet floor covering.............	220	820	0.06
Cushioned vinyl sheet floor covering			
Brand A (average of three tests).........	203	1,275	0.09
Brand B (average of three tests).........	197	2,083	0.15
Brand C..................................	220	2,932	0.21
Linoleum, 1/8-inch gauge, burlap backed.......	291	1,065	0.08
Wool looped pile carpet with hair pad (average of two tests)..................	188	8,462	0.61
Wool looped pile carpet with waffle sponge rubber pad (average of two tests)..................	176	8,379	0.60
Wool looped pile carpet with attached foam rubber cushion..........................	220	5,023	0.36
Acrylic looped pile carpet with hair pad (average of two tests)..................	178	9,456	0.69
Nylon looped pile tufted carpet...............	223	2,601	0.19
Nylon looped pile tufted carpet with attached foam rubber cushion....................	223	2,892	0.21
Nylon modified upholstery weave carpet with attached sponge rubber cushion..........	202	3,440	0.25
Nylon looped pile tufted carpet with attached sponge vinyl cushion...................	226	3,119	0.23
Nylon looped pile tufted carpet with solid vinyl backing...........................	227	2,004	0.14
Polypropylene felt carpet.....................	223	3,610	0.26

4.2.2 Apparatus (See Figure 5)

Compression-recovery tests were performed using a compression testing machine with a variable speed crosshead and electric load cell, connected to a chart recorder. Flat cylindrical plates were substituted for the upper and lower jaws. A square steel plate, 10- by 10- by 1-inch thick, was placed on the lower cylindrical plate. Pressure was exerted on the specimens by means of a cylindrical, flat indentor, 1.125 inch in diameter, 1 sq. in. cross section.

4.2.3 Procedure

In performing the test, the steel plate was first approximately centered with respect to the upper and lower cylindrical plates. The specimen was then placed on the steel plate and the indentor was placed on top of the specimen, in approximately the center, and the crosshead lowered so that the upper plate barely touched the indentor, holding it in place but not exerting any pressure. The controls were turned on and the crosshead lowered at a speed of 1 cm/min until the chart indicated a load of approximately 100 kg. The crosshead was then immediately reversed, so that a curve of compression-recovery was obtained.

4.2.4 Results

Typical compression-recovery curves of crosshead travel in cm. vs. force in kg. are shown in Figure 6. An ordinate was drawn from the peak of each curve. The area between the ordinate, the abscissa, and the compression part of the curve was taken as the energy of compression. Values for maximum force and energy of compression are shown in Table 1. In order to compare the results with data on the force exerted by people walking, maximum force was expressed in lbs. and energy of compression in ft.-lbs. In order to compare various floor coverings, the energy of compression was reduced, in each case, to a basis of 100 lbs. maximum force, expressed as ft.-lbs. per 100 lbs. Since the force, in each case, was exerted over 1 sq. in. area, the maximum force values are also maximum pressures in lbs. per sq. in.

4.2.5 Discussion

The relative values for energy of compression were about what one would expect. Firm materials, such as asphalt and vinyl asbestos tile, showed low energy values, while relatively high energy values were obtained with soft materials, as carpets with rubber cushions etc. This correlates with subjective experience. A person feels the difference between a hard and a soft surface. Carpets feel more "cushiony" and comfortable. However, the energy values are all low, never more than a fraction of a ft.-lb. This agrees with the observations of T. S. Holden and R. W. Muncey in "Pressures on the human foot during walking", Australian Journal

of Applied Science, vol. 4, No. 3, page 405 (1953). Holden and Muncey state that "Variations due to changes in floor surface are almost non-existent, the only noticeable effect being the disappearance of a small impact peak when the subject changes from ordinary floors (concrete, wood) to lawn" and "At first sight it is surprising that the curve for a relatively soft floor like cork tile is almost identical with the curves for wood and concrete. This is probably because in the system foot-sock-shoe-floor the deflection under load occurs almost completely in the flesh area between the skin and the bone of the heel and the difference in the deflections in cork and concrete, due to their different Young's moduli, is completely obscured. For the lawn, where the deflection is likely to be comparable with that of the flesh, the impact peak disappears".

Further information on the mechanics of walking and the dynamics of the human body can be obtained from the following publications:

National Bureau of Standards Technical News Bulletin 35, No. 4, 501 (1951), "Electronic Stepmeter Reveals Mechanics of Walking"

Don M. Cunningham and G. Wayne Brown, "Two Devices for Measuring the Forces Acting on the Human Body During Walking", Proc. Soc. Exp. Stress Anal. 9, No. 2, 75 (1952)

F. C. Harper, W. J. Warlow, and B. L. Clarke, "The forces applied to the floor by the foot in walking", National Building Studies, Research Paper 32, Her Majesty's Stationery Office, London, England, 1961

5.0 SUGGESTED PERFORMANCE REQUIREMENTS FOR FLOOR COVERINGS

1.0 Health and safety

1.1 Sanitation; control of biological environment

1.2 Air pollution control; soil transport into the atmosphere

1.3 Fire safety

1.3.1 Fire resistance
1.3.2 Maximum flame spread
1.3.3 Maximum smoke development rating

1.4 Slip resistance

1.5 Resistance to development of static charge and dissipation of charge

2.0 Maintenance

2.1 Floor cleanliness

2.1.1 Soilability and cleanability; routine maintenance as vacuuming, shampooing, washing, waxing, polishing

2.1.2 Stain resistance and ease of stain removal; spotting

2.2 Repairs and replacements including patching

2.3 Durability; wear; life expectancy

3.0 Comfort and convenience

3.1 Moisture and solvent permeability and retention; resistance to solvents

3.2 Resilience as related to foot comfort and bodily protection

3.3 Resistance to movement of wheeled vehicles; static and rolling friction

3.4 Noise control; acoustical properties

4.0 Economics

4.1 Initial cost; amortization

4.2 Cost of maintenance including repairs and replacements

6.0 PROPOSALS FOR FUTURE WORK

6.1 Inspections of hospital installations

The first step in the continuation of this study is to establish performance requirements for hospital floor coverings. This must be done by a study of actual installations. At least one of the NBS staff members should visit existing installations. One installation which should be inspected is the Lutheran General Hospital in Park Ridge, Illinois. This installation has been studied thoroughly but needs unbiased observations. Another hospital carpet installation should be studied, one on which little has been reported and preferably not too far from Gaithersburg. Candidate installations are Atlantic City Hospital; St. Mary's Hospital, Orange, N. J.; and the Veterans Administration Rehabilitation Center in East Orange, N. J.

6.2 Field experiment

In addition, it is essential that a field experiment be performed under Bureau supervision. An agreement has already been completed between the Building Research Division and the Clinical Center of the National Institutes of Health. Under this agreement, carpet would be installed in a nursing unit in the Clinical Center. The staff members of both NBS and the Clinical Center would cooperate in chemical, physical, and biological tests, and in a maintenance cost study. This would, of course, enable valuable correlations between use conditions and laboratory tests.

It would also provide information as to the advantages and disadvantages of carpet as a hospital floor covering and evaluation of different types of carpet. Perhaps a more important output would be a better understanding of performance requirements. Practical independent observations should enable the Bureau to determine what are the needs and preferences of the patients and staff and what are the problems.

6.3 Test methods

The stated objective and certainly the soundest is a systems approach to the problem, based on prior establishment of performance requirements. However, the NBS and the Public Health Service agreed that certain factors should be studied and others should be excluded. It was agreed that fire hazard would be outside the scope of the present study. Acoustical properties, while included in the study, will be the subject of a separate report. Biological studies are planned to be included in the proposed field experiment and will be the responsibility of the Clinical Center. Proposals for work on other performance tests will be discussed under headings which follow.

6.3.1 Slip hazard

Falls, both on a single level and from one level to another, constitute one of the greatest causes of accidental casualties (See Vital and Health Statistics Data from the Nation Health Survey, U. S. Department of Health, Education, and Welfare). This area is one where research appears to offer possiblilities for reducing the incidence and effect of the hazards. A principal cause of falls is the slipperiness of walking surfaces. An examination of the standards and data, available to implement a requirement that floors and walkways shall not present a hazard of falling caused by this slipperiness, indicates that a research project should be initiated along the following lines:

1. Development of a standard and generally acceptable method of determining the slipperiness of floors, including the development of any necessary test equipment or devices.

2. Determination of the quantitative criteria for slipperiness that will provide the requisite level of safety throughout a building. For example,

    a) Areas of high liquid spillage or areas where rain or snow are tracked inside the building should have different consideration than continually dry areas.

    b) If more than one type of floor covering is used within a building, the possibility of slipping or tripping is greatest where two materials of widely different slip resistance adjoin.

3. Examination of walkway materials for their performance under the above requirement after being subjected to wear and maintenance.

6.3.2 Resistance to wheeled equipment

A test method for determining the resistance of a variety of floor coverings to static and rolling friction of a wheeled hospital bed has been developed under this project. The variables in this test were caster hardness, load conditions (empty, empty plus live load), as well as floor coverings. The test requires a platform, 4- by 12-feet in size, to which the floor covering to be tested is applied. The need for a test procedure that would use a smaller wheeled vehicle whose weight could be adjusted to simulate the variety of hospital vehicles used in service is necessary. Such a vehicle could be designed to accomodate the variety of casters available for wheeled vehicles. Financial savings would be realized because test floors need not be as large. These smaller floor assemblies could be stored for possible repetitive tests after scheduled soiling and cleaning techniques were applied.

Correlation of results of such a test procedure with the results of tests already performed with the hospital bed could be attained. The new test could then be adopted as a standard acceptance test. The establishment of such a standard test would benefit government agencies in that new materials could be readily evaluated to determine their suitability as coverings for hospital floors.

6.3.3 Static electricity generation and dissipation

The ideal way to eliminate static charge is to maintain the humidity at a relatively high level at all times. Static is not a problem when the relative humidity is 50% or higher. However, most hospitals are not so equipped to maintain these conditions and are not likely to be in the near future. The problem is to evaluate floor coverings, especially carpet, for static build-up and decay.

A considerable amount of research has already been done at the NBS on the static problem as is evident from the following NBS Reports:

"Static Electricity Generated in Fibrous Materials",

Herbert F. Schiefer and Francis L. Hermach, NBS Report 4158, June 30, 1955

Francis L. Hermach, NBS Report 4455, December 30, 1955

Jack C. Smith, NBS Report 4752, July 12, 1956

Jack C. Smith, NBS Report 5267, May 1, 1957

"Conductive Flooring for Hospital Operating Rooms",

Thomas H. Boone, Francis L. Hermach, Edgar A. MacArthur, and Rita C. McAuliff, NBS Report 5729, January 20, 1958

Information has also been obtained from the carpet industry on current research in the evaluation of anti-static sprays for carpets.

It is proposed that a desk study be made of the state of the art in static test methods. This would be combined with field tests in the proposed hospital carpet installation.

6.3.4 Resilience of floor coverings in relation to fatigue and bodily protection

Laboratory studies which were conducted under the project and are reported in section 4.2 were intended to study the relationship between subjective impressions or actual physiological comfort and energy of compression. It is doubtful that soft floor coverings contribute physically or physiologically to bodily comfort. It seems likely that the effect is largely psychological. A closely related characteristic is bodily protection from falls. The question here is whether soft floor coverings cushion the body enough to reduce injuries from persons tripping or slipping and then falling on the floor.

At this stage the most useful information should come from the proposed hospital study. This will require cooperation from the hospital staff, who will provide opinions on the relative comfort and possible physiological merits of carpet and smooth floor coverings. This will come from their own personal experience and professional training and from observations of persons walking on both carpet and resilient tile.

6.3.5 Soil transport

Floor coverings pick up dirt mainly from shoes of persons walking in from the outside. A large part of the dirt is deposited near the entrance. For this reason, walk-off mats have become popular. Of course, walk-off mats will not remove all of the dirt, especially when the mats become soiled and matted. It is possible that dirt might be picked up from a soiled walk-off mat and deposited on other floor areas. The dirt might be stirred up from walking and dispersed into the atmosphere of the building. Likewise, floor coverings elsewhere in the building may transfer dirt to other floor areas or into the air. This is what is called soil transport. One type of soil transport is surface transport, meaning the transport of dirt from one floor area to the other. Air-borne soil transport is the transport of dirt from the floor to the air.

If a floor covering is to retain the soil deposited on it instead of spreading it to other areas or dispersing it into the air, it must have some attraction for dirt. At the same time, it must not have too strong an affinity for dirt or it will become easily soiled and hard to clean. Obviously some balance of properties is needed and some areas will need a floor covering which attracts and retains dirt to a greater degree than would be desirable in other areas.

Since there is no test method for soil transport, a field and laboratory study is required in order to develop a method. The amount of dirt picked up from floor surfaces has been measured by wiping with special cloth strips and either weighing the strips or measuring the dirt with a densitometer. This method is described by Robert J. Weatherby, "The measurement of floor dirt", Journal of Environmental Health, vol. 26, No. 4, 239 (Jan.-Feb., 1964).

A method for sampling the total dirt on a floor covering has been developed by Corwin Strong of the Department of Environmental Sanitation Control, Clinical Center, National Institutes of Health. Unlike Weatherby's method, which samples only surface dirt, this method samples all the dirt on the area of floor covered by the device. The device used is a brass ring, sharpened with the bevel on the outside, so that the inside is a cylinder 6 inches in diameter. The ring is provided with a handle for pressing against the floor. Carpets are sampled by pressing the ring on the surface to form a seal. Smooth surface floors are sampled by first placing an O-ring around the edge of the brass ring, then pressing on the surface. The ring is pressed against the floor and a measured amount (200-250 ml) of a solution of wetting agent (as TRITON X-100, CHEMIDINE) is added. The surface inside the ring is scrubbed with a fiber brush and a portion of the suspension sucked up with an ear syringe. The suspension is added to a graduated centrifuge tube (a 10-ml aliquot is generally taken). The suspension is centrifuged and the volume of soil measured. See Figure 7.

Methods of air sampling have been discussed in several meetings between the staff of the Bureau and the Public Health Service. This type of measurement is important in evaluating floor coverings for air-borne soil transport. According to Dr. Charles M. Hunt of NBS, the particulate count fluctuates considerably in laboratory measurements, so that some kind of continuous monitoring would be necessary in field tests. The only practical kind of continuous samplers are the paper tape sampler and the light scattering counter. A paper tape sampler would probably read lint, as from carpet fibers, but would not separate or identify this type of particle. The electronic light scattering type is best for small particles but is biased in favor of particles less than 1 micron in diameter and is intended more for "clean rooms". In a hospital room, larger particles tend to settle in the room and are more of a cleaning problem than are small particles. Also, smaller particles tend to coalesce. In addition, an entrapment method would be valuable for identification of the particles. In a slit sampler or cascade impactor, particles are passed through a succession of four slits of different widths and particles are caught on an adhesive surface. This enables a determination of relative amounts of particulate matter.

It is recommended that a study be made of available methods for surface and air sampling and appropriate methods be used in the hospital study.

Figure 7. Device for sampling floor dirt

6.3.6 Durability

It is important for a floor covering to be durable or to retain its properties for as long a time as possible. All floors are subject to wear, which changes the appearance, thickness, and integrity. In time a floor covering will actually wear through its thickness, as by abrasion from shoe soles etc. Before the material is actually worn through, the texture and pattern will usually be destroyed. Smooth floor coverings will scratch and mar and become hard to clean. Carpets or pile floor coverings will become matted, torn, and spotted.

Durability is a very difficult property to evaluate. No laboratory test method has been devised which will correlate durability with physical measurements except within a limited range of materials. One problem, which must be decided by the consumer, is the expected life of the floor covering and the desired level of appearance.

In a test for durability, use conditions are supposed to be accelerated and a change in the product is measured. Usually what is measured is a change in a physical property which is considered to be desirable by the consumer. For example, an abrasion test on a smooth surface floor covering might result in a lower value for gloss or a loss in thickness, which might destroy the pattern or actually wear through.

One method of evaluating change in floor coverings due to wear is by comparing photographs before and after use of accelerated test or by comparison to reference photographs. This method is used in ASTM D 2401-67, Standard Method of Test for SERVICE CHANGE OF APPEARANCE OF PILE FLOOR COVERINGS.

A tremendous amount of research has been done on wear or abrasion resistance of floor coverings. An excellent review article was written in England by F. C. Harper, "The Abrasion Resistance of Flooring Materials - A Review of Methods of Testing", Wear, vol. 4, pages 461-478 (1961). The scope of the article is described in the Summary, "A general discussion of methods of testing the abrasion resistance of flooring materials by fundamental methods, field trials, and abrasion machines, with criticisms of methods and proposals for a new approach". This new approach is one based on a basic study of the forces applied by the foot to the floor in walking and turning on the level.

The NBS wear machine was developed at the Bureau and used successfully for testing wool carpets. This machine is described in the following articles:

Herbert F. Schiefer and Richard S. Cleveland, "Wear of Carpet", RP640, J. Res. NBS, Vol. 12, 155 (February, 1934)

Herbert F. Schiefer, "Wear Testing of Carpets", RP1505, J. Res. NBS, Vol. 29, 333 (November, 1942).

Mr. M. Romer of Aldon Rug Mills, Inc., Lenni Mills, Pennsylvania 19052, has given the Bureau a copy of a report dated March 26, 1965 from the United States Testing Company, Hoboken, New Jersey 07030, in which a modification of the NBS wear machine was used to evaluate nylon carpets. In view of the recent industrial interest in this testing device and previous Bureau experience, it is proposed that a further study of the NBS wear tester be made of samples of carpet used at the hospital test installation. Attempts should be made to correlate field observations with laboratory tests.

6.3.7 Soilability and cleanability

It is proposed that a further study be made of industrial and published methods and an attempt made to evaluate existing methods and, if necessary, develop a new method. The best method available would be used to test samples of carpet used in the proposed hospital installation.

6.3.8 Staining and removal of stains

A review of stain removal methods and a discussion of candidate stains will be the subject of a separate report. By consultation with the staff of the Clinical Center, candidate stains would be selected which are a problem in the hospital. Simulated standard stains would be tried in research on a laboratory method for evaluating floor coverings for staining and stain removal. Based on reported methods for stain removal, standard methods would be developed for the laboratory test. Staining and stain removal tests would be performed on samples of carpet used in the proposed hospital installation.

6.3.9 Moisture permeability and retention and solvent resistance

Laboratory research would be done on a test method for moisture permeability and retention and solvent resistance of floor coverings, especially carpet.

6.4 Replacement and repair including patching

The Bureau is in close contact with manufacturers and installers of carpet and smooth surface resilient floor coverings. It is proposed that these contact be maintained and that the Bureau remain knowledgeable in the latest techniques of repair and replacement of both old and new floor coverings.

6.5 Maintenance cost

One of the most important studies which are proposed for the test installation at the Clinical Center is a study of costs of maintenance of resilient tile and carpet. A number of studies have been published and are available for use as models. Some of these are in the form of booklets from the American Carpet Institute and the Asphalt and Vinyl Asbestos Tile Institute.

A time and motion study was made of commercial and institutional installations in the Philadelphia area, including office buildings, department stores, hospitals, apartment buildings, restaurants, and schools. The reference is George M. Parks, "The economics of carpeting and resilient flooring", University of Pennsylvania, The Wharton School of Finance and Commerce, Industrial Research Unit, Philadelphia, Pennsylvania 1966.

Published articles on maintenance cost studies in hospitals include:

Mildred Chase, "Sanitation Problems of Hospital Carpets", Hospital Management, August, 1965

Joseph T. Creco, "Carpeting vs. Resilient Flooring", Hospitals, Vol. 39, June 16, 1965

6.6 Effect of floor coverings on biological environment

It is proposed that a study be made of the effect of covering existing asphalt tile with carpet on the biological environment of the proposed test installation. In this study, the biological tests would be performed and evaluated by the staff of the Clinical Center.

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